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September 1989
NSRP 0310

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1989 Ship Production Symposium

Paper No. 11: Harnessing Simulation of Naval Shipyards

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page	Form Approved OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 1989	**N/A**	-

4. TITLE AND SUBTITLE	
The National Shipbuilding Research Program 1989 Ship Production Symposium Paper No. 11: Harnessing Simulation of Naval Shipyards	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**11**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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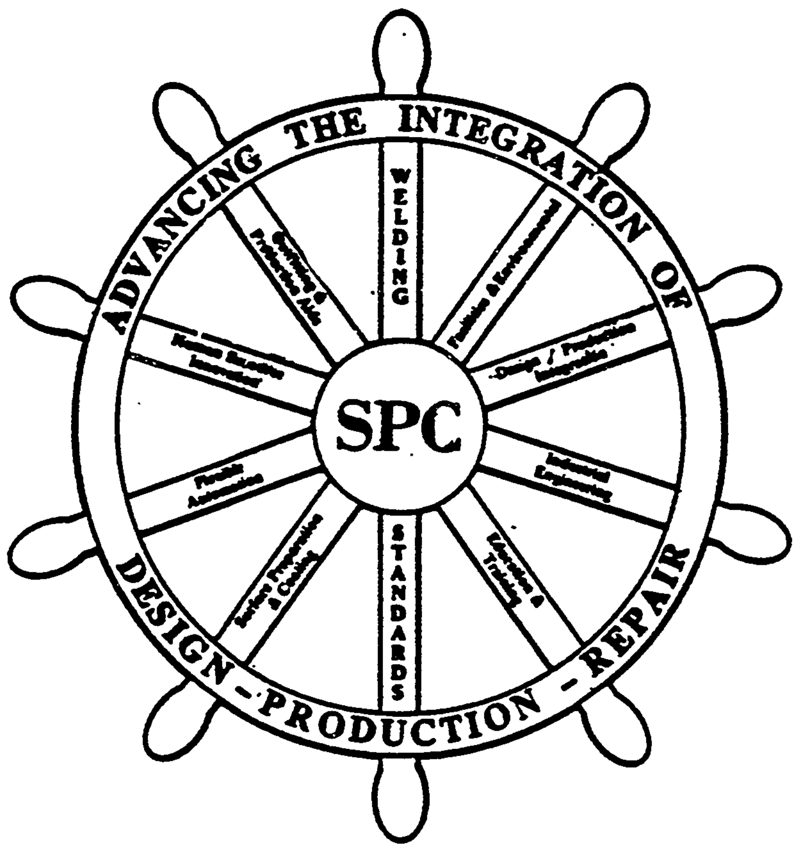

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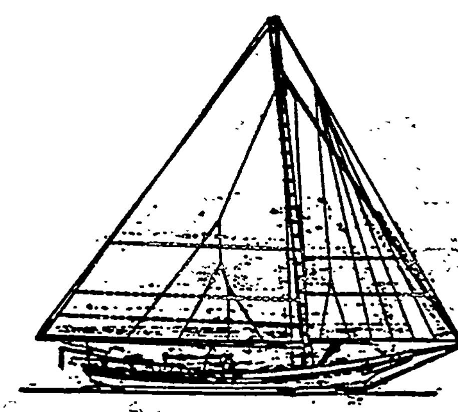

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601 Pavonia Avenue, Jersey City, NJ 07306
Paper presented at the NSRP 1989 Ship Production Symposium
Sheraton National Hotel, Arlington, Virginia, September 13 - 15, 1989

No. 11

Harnessing Simulation of Naval Shipyards

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HARNESSING SIMULATION FOR THE NAVAL SHIPYARD

Managers in the shipyard environment, no less than any other industry, want a reliable and cost-efficient method for analyzing information and guiding decisions. The bottom line is discovering the most productive utilization of limited resources for the maintaining of nation's defense. With personal computers on the desks of many technical managers and industrial engineers, computer simulation has become a realistic and valuable tool for planning, evaluating, and implementing industrial processes.

Simulations make it possible to study the behavior of systems so complex that known analytical models cannot represent them accurately. Simulations model real systems. The models capture the key relations among elements of systems. Discrete-event models represents processes as sequences of independent events. Discrete-event simulation projects and evaluates the impact of changes that could be made to a system, without incurring the expense and risk of trial and error within the system itself.

Simulation development systems for the microcomputer offer analysts and managers tools that can fit any number of decision support uses. Simulation software is being used by the military, civilian government, and private enterprise for applications ranging from transportation, warehousing and materials *resource* planning to Flexible Manufacturing System uses. These tools are proving invaluable for the evaluation of proposed systems or policies.

Simulation provides Naval Shipyard personnel an important opportunity to utilize existing hardware to meet new challenges . The approach has been applied only minimally in the shipyard environment. The Simulation Workshop planned for mid June in the Washington D.C. area, will provide an opportunity for managers and engineers to explore the uses of simulation to meet real needs. This workshop will prepare participants to evaluate shipyard activities as subjects for simulation, estimate the investments required to perform simulation, and project the potential benefits.

HARNESSING SIMULATION FOR THE NAVAL SHIPYARD

I. THE CHALLENGE

The Naval Shipyard presents a full spectrum of management challenges and engineering applications. Work packages that include detailed specifications and time schedules must be prepared. Consider the headaches of berth scheduling, on-board ship maintenance, inspections, component disassembly, refurbishment and reassembly in the shipyard machine shop, materials handling and transportation. All of these demand careful distribution of resources: space, equipment, tools, labor, and skills.

Where are the potential bottlenecks in your new assembly line design? Do you need eight forklifts or ten? How often does such and such a piece of equipment fail? Would an extra shift be a cost-effective means of improving performance? The botton line is discovering, within the confines of time and budget restrictions, the most productive utilization of limited resources for the maintaining the nation's defense. Accomplishing this *ongoing* task requires the analysis to vast amounts of information.

Managers in the shipyard environment, no less than any other industry, want a reliable and cost-efficient method for analyzing information and guiding decisions. We naturally turn to computers. They can help us make decisions by gathering, organizing, evaluating and displaying information in forms we can assimilate and understand. Computers have long been familiar to us as managers of information, whether for our personal checkbook accounting, the automobile dealers' parts inventory, census data, airline flight schedules, or, of *course,* the IRS. As sophisticated software tools have been developed, computers have become an integral component of every major weapons system. Computers also have become prominent in manufacturing for process control, plant management and *engineering* design. In recent years computers of ever-increasing power and speed have become available to lower costs. The microcomputer explosion has placed personal computers on the desks of many technical managers and engineers. This trend is providing access to a computer tool tremendous potential benefit to the Industrial Engineering World. The tool is Simulation.

Computer simulation is serving military and civilian government, and private enterprise. The specturm applications range from determining a realistic launch schedule for the Space Shuttle to optimizing service at McDonalds. Simulations have been used to analyze air traffic control, telephone switching systems, and factory layouts. The illustrations are abundant. For example:

- Hughes Aircrait used simulation to help determine equipment and per*sonnel needs* as well as the factory layout for their ADCAP Torpedo production facility.
- Caterpillar, Inc. has simulated the impact of two FMS (Flexible Manufacturing System) design alternatives, and the transportation of parts by van versus flatbed.
- The U.S. Army used simulation to evaluate and validate the capacity and line balance of production activities and work station sequences for new facilities at the Red River Depot.

II. THE APPROACH

To examine computer sibilation as a valid approach to industrial analysis, we need to consider a *general* descrip-tion of what simulation has to offer. Secondly, we can better envision the potential of simulation through a practical illustration of a discrete event simulation model. Thirdly, with the illustration in mind, we will look briefly at the basic methodology, and finally, survey the potential Output.

A. GENERAL DESCRIPTION OF SIMULATION

Simulations differ from many com-computer applications *in* the view they present. They enable us to view what can be, rather than what has been. Simulations make it possible to study the behavior of systems so complex that known analytical models cannot represent them accurately. Analytical methods fail to provide answers to many of the questions that managers have to ask when making real decisions. Simulation methods help analysts and managers organize their intuitive understanding of industrial processes that involve complex interactions and uncertainties. In turn, better understanding of industrial processes leads to strategies for improving operations.

Simulations model real systems. Typical subjects include queueing networks, non-linear, multivariable stochastic processes, and feedback in networks. The models capture the key relations among elements of the real systems. We may believe, for example, that a parts bin behaves as a queue and down time of a machine has an exponential distribution. We may have data describing the behaviors of these elements, but no idea of how they affect each other or the larger process. Simulation helps us understand the interactions involved. lt may also show us how to change the elements to improve the larger process.

The dynamics of some processes can be simulated by continuous simulation methods, others by discrete-event methods. Continuous models represent

processes as systems of differential equations. Discrete-event models represent processes as sequences of independent events. A checkout counter and its customers are a "discrete event system"; a swinging pendulum is not. Continuous models are deterministic; they assume that rates of change remain fixed over time. A discrete-event model may be stochastic. That is it can accommodate random variables. This allows us to study the behavior of the system as it is influenced by random events of different moments in *time.*

B. PRACTICAL ILLUSTRATION OF A DISCRETE EVENT MODEL

To understand the potential usefulness of a discrete-event model, let's examine a discrete event system that most people have experienced: a typical "deli". We'll call ours Phlasch's Deli. A deli is the culinary equivalent to a custom machine shop.

The manufacturing process of a sandwich surely should be *familiar* to the shipyard manager: getting components from inventory, processing products to precise tolerances (only golden brown toast), maintaining quality control of materials and workmanship, and avoiding rework. (It's not appropriate for the deli operator to sample or test the finished product before delivering it to the customer). Then there is assembling and packaging and maintaining quick turnaround. Other similarities come to mind: irregular ordering schedule, process bottlenecks, equipment breakdowns. Sound familiar?

Our task is to model this total system we know as a deli. To define the model we must:

0 Describe the deli
0 Identify the processes
0 Define the variables

1. DESCRIBING THE DELI

If we asked someone to describe Phlasch's Deli, they might respond: "Phlasch's Deli. ..a little shop on 34th and 8th, good hot or cold sandwiches, okay salad, a great bratwurst, quick service". Accurate enough -- if *you are a* potential customer. But not the right perspective if *you* want to model the deli as a discrete event system.

Our description of the deli must be expressed in terms of events, actions, processes, and elements that cause or influence them.

PHLASCH'S DELI

Just off the beaten track; mixed residential and office; near a subway station busy period from mid-morning through early evening; frequent surges of customers; most people in a hurry; room for only ten people to wait in line inside the shop.

THE MENU

All sandwiches made from scratch; some require toast; some hot meat; some baking; soups, salads, bratwurst prepared in quiet periods.

J.J. PHLASCH

Owner and sole employee; order taker; sandwich maker; server; and cashier. (This is a very small deli.)

THE EQUIPMENT

Toaster; steamer for heating meats; oven for baking subs with melted cheese; one hot plate each for soup; bratwurst, and sauerkruat.

2. IDENTIFYING THE PROCESSES

From these descriptions of system elements, we must identify the information that has a bearing on the occurrence of events. With this information we can identify the interaction of the elements in terms of system processes or sequences of events.

PHLASCH's DELI

The real item of interest here is "customers", specifically:

0 how frequently customers arrive
0 how long customers are willing to wait
0 what customers order how often

We can gather this data by observing the deli for a few days and recording what we see (in the form of distribution tables.) We will record the intervals between customer's arrivals, the number of customers not joining or leaving a line (when it's one, two..or twenty people long), and which items on the menu are ordered how often.

THE MENU

A customer's order begins a sequence of events that is determined by what the customer chooses from the menu--the order type. Orders are typed according to the actions and equipment required to prepare them. The order types are sequences of tasks processed by J.J. Phlasch. Reubens and steak and cheese subs are of a type that requires assembly actions and use of the oven to melt the cheese. The order type including egg salad on whole wheat and roast beef with lettuce and mayo on pumpernickel, requires only assembly actions.

J.J. PHLASCH

J.J. executes the tasks and arbitrates the priority of tasks when two or more tasks are presented simultaneously. He is governed by a set of rules that can

be determined from observation. These rules might include being sure, when ever there is a line, that at least x number of customers have. given their orders. A customer that has given his order is less likely to leave. Another rule might be that the cash must be collected as each order is served, no matter how many customers are waiting. These rules tend to "Batch" J.J.'s tasks but they do not necessarily make the most efficient use of the equipment.

THE EQUIPMENT

The toaster, steamer, and oven each represents a potential bottleneck as a limit on the souce of supply at any one time. For each one, we need to know the process duration (length of time it takes to toast, melt cheese, etc.) and the capacity (the maximum number of items that *can be* handled at one time). We also need to know the meximum nymber of servings the containers of salad, soup, bratwurts, and sauerkraut will hold, and the length of time it takes to replenish the supply when the containers are empty.

3. DEFINING THE VARIABLES

Now we can express the system, Phlasch's Deli, as a set of specifications:

- Customer's arrival interval
- Customer's tolerance (likelihood of joining the waiting line)
- Customer's menu preference
- Task sequence for each type of menu selection
- Processing rules by task priority for J.J. Phlasch
- Process duration and capacity for each item of equipment

We must collect observations for each of these variables and construct tables of sequence of values. Our model will require distribution tables for customer arrivals, customer orders, customer tolerance (for waiting in line), order type processes, the duration and capacity of the equipment, and any other variables we have defined.

C. BASIC METHODOLOGY

The computer program that would execute the deli model we have just described has three parts. The first is a program that generates a schedule of customer arrivals. We choose a "period of interest" to model, for example, 11:00 a.m. to 2:00 p.m. The program begins by setting the model clock. The starting time must be earlier than the period of interest so the model can reach a steady state. To model the hours of 11:00 - 2:00, the clock will start at 10:30 a.m.

The program selects the first random number between 0 and 99. The model clock is moved ahead by an increment of time. The increment is determined by the Customer Arrival Table according to the <u>range</u> of random numbers in which the selected random number falls. The process is repeated until the model clock time exceeds 2:00 p.m., the time of day we have chosen as the end of the period of interest. The list of customer arrival times that has been created by the program "primes the pump" for the model.

The second and central component of the model, the event processor, starts with the first customer. It uses the Customer Order Table plus the random number generator to determine an order type. The events generated by ordering a meal are meshed chronologically with the arrival of customers. The process rules that represent J.J.'s decisions about which events take priority are executed *as* program logic. The rules might include deleting a customer from the input queue if the number in line exceeds the customer' tolerance for waiting (determined by a role of the dice and the Customer Tolerance Table). The event processor will reschedule an event that needs a piece of equipment that has reached its capacity.

The event processor documents the occurrence of key events that will contribute to the model analysis. For example, customer arrival, meal selection and selection time. Optimum process time (if this were the only customer) and real process time will be documented, as well *as* the delay time for events waiting on full equipment or a busy J.J.

The third component of the system is a program that gathers up the output of the event processor, and aggregates the data. Reports from this component can be used to identify the loss of customers due to line lengths, and the delay time due to J.J., or to each piece of equipment. The products of the entire model could be represented as a single report or could be input to a statistical or graphics applications for further processing and display.

D. POTENTIAL OUTPUT

A single execution of a discrete event model such as our deli model would create one arrival schedule and one set of output data. This single iteration would not shed much light on system performance. For the output data to be useful, the model needs to be executed against a randomly generated schedule for arrivals. Then performance characteristics can be observed under different loading conditions. The model is validated by matching specifoc sets of observable data against observed sets of results.

Our operational model will measure the efficiency of the deli. The output data tell us how close to optimum time

customers are processed through the deli. The two factors within the model that impact the efficiency are resource limitations (J.J. and his equipment), and process complexity (menu options).

Our model can be used to examine the impact of resource changes, such as adding another toaster, bringing in J.J.'s brother-in-law to work part time, etc. It can be used to evaluate theimpact of various changes in the menu.

In other words, the benefit of this discrete event simulation is to project and evaluate the impact of changes that could be made to the system, without incurring the expense and risk of trial and error within the system itselt.

The random element in our model has been introduced in the input queue of customers and meal selection. But random events such as equipment failure or dropout rates, could be incorporated as well. The value of discrete event simulation is the capability of evaluating the system under changing load conditions or unusual sequences of events.

III. RESOURCES

As useful as simulation may be, is it accessible to the shipyard manager or engineer, and is it affordable? To answer the question of resources, we will survey computer technology possibilities, and describe the ~~the~~ ~~soft~~ware available.

A. COMPUTER TECHNOLOGIES

"Simulations use up all the money and all the time. . .", Bjarne Stoustrup, AT&T researcher and former simulation addict, explains to an audience of programmers. Stoustrup says that he developed the first versions of the C++ compiler, the subject of his popular seminar, because he had used up the department's monthly computer budget during one series of simulations. The C++ compiler helped make it economically feasible to perform the simulations on a powerful mainframe. (1)

Many of the managers who have tried to keep simulation projects within budgets share Stoustrup's assessment of mainframe simulation technology. While useful for some applications, mainframe simulation programs can easily get out of control. However, many of today's engineers and technical managers have personal computers available to dedicate to simulations and other operations planning tasks.

Complex simulations which run smoothly on upgraded versions of desktop computers provide distinct economic advantages over their mainframe ancestors. For one thing, the microcomputer programs cannot drain computer resources away from other users. Just as important, users find the programs much more accessible than the mainframe simulation languages. The wide range of microcomputer products available for developing simulations offers the potential user a choice of capabilities and costs. And alternative and complementary modeling systems further extend the user's options.

B. SOFTWARE PACKAGES

A number of vendors offer simulations development systems for microcomputers. Four of the most widely used are:

SIMAN/CINEMA by Systems Modeling Corporation
SIMSCRIPT II.5/SIMANIMATION/SIMFACTORY by CACI
SLAMII/PC ANIMATION by Pritsker end Associates
GPSS/H by Wolverine Software Corporation

These are complete development systems that produce separate program modules for model and experiment. They are capable of supporting discrete-event and continuous simulations, sequences and time schedules, graphs and full animation. They include varying combinations of capabilities including macro sub-modeling, dynamic memory allocation, program development tools, special functions for materials handling and robotics, support for autocad and other popular software, real-time and interactive animation, and EGA bitmapped graphics. Some permit the transfer of microcomputer models to mini and mainframe computers.

Developer programming is requisite with these systems. They compile simulation programs written by a developer, and display the simulation program output in graphic mode. A simulation developer typically needs from one day to one week of formal simulation training, some programing experience, and operations analysis experience in order to get started. Complex model development requires more training and experience. The manufacturers usually offer free technical support for varying lengths of time, support users' groups, and distribute newsletters.

These systems run on an IBM AT or compatible with 4-6 MB of fixed disk space, an 80287 or comparable floating point numeric co-processor, an EGA graphics card and display, and a FORTRAN compiler version 4.1. These total software systems sell for $5,000 to $15,000.

Cost of simulation development and use vary widely; so do benefits. The costs of the development packages we are discussing actually seem low, relative to purchase and lease fees for mainframe software. Often these costs exceed the costs of the microcomputer software

1 Bjarne Stoustrup - C++ Seminar

and hardware combined. Replacing mainframe simulation development systems with microcomputer systems usually lowers the cost for the same result.

Development of large simulations from scratch realistically requires a week of formal training for each developer, a week or more of programming time, a minimum of several weeks of data collection and a week of running the simulation and analyzing the results.

Large-scale projects with substantial benefits for improvements provide the best justification for the set up costs of simulation. However, a simulation development system set up on a PC largely dedicated to simulations, but shared by several users, would bring costs down to an appropriate level for small projects. Cost efficiency can be increased by *using* the PC's for demonstrations, planning exercises and training, as well as for simulations of operations.

IV. APPLICATION

Microcomputer simulation development systems offer analysts and managers tools that can fit any number of decision support uses. Simulation programs are valuable to manufacturers, who have a strong interest in Flexible Manufacturing System (FMS) applications. They are used for transportation, warehousing and materials resource planning (MRP) applications. And they are invaluable for the evaluation of proposed systems or policies.

By replacing the usual flow diagrams and schedules with computer graphics and worksheets, simulation helps analysts to quuantify work flows. Simulation adds another dimension to computer graphics and displays. It lets analysts introduce effects of uncertainty on work flows and scheduling. Since the choice of such production strategies as "Just in Time" (JIT) or Optimised Production Technology" (OPT) depends on uncertainties in the production process, simulations work when methods based on certain knowledge do not.

Simulation can help streamline and improve any operating plan that requires a formal "walk through" before implementation. Animated simulations show objects on a screen behaving as actual objects should. A game based on simulation can help train a person to identify radioactive contaminants. Planners can study how on-site assembly might interfere with installation operations. Simulation can help us cope with complex interactions among uncertain events.

Simulation provides Naval Shipyard personnel an important opportunity to Utilize existing hardware to meet new challenges. The tool has been applied only minimally in the shipyard environment. NAVSEA 07's PIERS product has produced a test version of a product that approaches simulation. It is program using a Lotus 1-2-3 worksheet and macro that simulates the effect of variability and allowance factors in the completion of work packages. The work packages include tasks involved in implementing an industrial process. Though useful, the program provides only a preview of the complex simulation available through the full simulation development packages we have discussed.

B. NEXT STEPS THE WORKSHOP

From examples of successful applications of simulation we can begin to appreciate the potential results that this tool might yield in the shipyard. However, the investment in computer resources, simulation software and user training is not insignificant. The Naval community needs to continue to explore the possible range of applications, the potential value, and the means for acquiring this capability. This exploration is the purpose of the Simulation Workshop planned for mid June in the Washington D.C. area. (2)

The workshop will bring together the shipyard experience of Industrial Engineer and the modeling experience of the simulation product specialist. The real needs of the shipyard *will be examined* and evaluated as candidates for simulation. Shipyard managers and engineers will have the opportunity to examine the technology first hand.

Busy managers and engineers engaged with the everyday workload are hard pressed to take a creative look at problem areas, much less at long-range solutions. But unless our shipyard personnel identify needs, they cannot use simulation to discover improvements in their working processes. The workshop will provide an objective environment for exchanging information and brainstorming.

At the end of the workshop managers and engineers will be able to view the shipyard environment with a modeling perspective. They will learn to recognize where simulation could be useful and what sort of results they can except. They will also have a better understanding of the software tools available to them and the resource investment required.

This workshop will prepare participants to:

- Evaluate shipyard activities as subjects for simulation
- Estimate the investments required to perform simulation
- Project the potential benefit

2 The Simulation Workshop was still planned as of the writing of this paper, and hopefully will be completed by the time this paper is presented.

The synergy of a workshop exchange can lead to new understandings of the potential of simulation and constructive planning for its utilization. Our goal is to develop a commitment to simulation as an approach to problem solving and a consensus for a coordinated approach to its use in the Naval Shipyard.

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